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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.:
Demande n°:
00125983.7

Anmeldetag:
Date of filing:
Date de dépôt:
28/11/00

Anmelder:
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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Methods, optical recording apparatus using these methods and optical recording medium for use by the methods and the apparatus

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat:
State:
Pays:

Tag:
Date:
Date:

Aktenzeichen:
File no.
Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

Methods, optical recording apparatus using these methods and optical recording medium for use by the methods and the apparatus

The invention relates to a method for setting an optimum value of a write parameter for use in an optical recording apparatus for writing information on an optical recording medium by a radiation beam, the method comprising a first step of writing a series of test patterns on the recording medium, each pattern with a different value of a write power level (P) of the radiation beam, a second step of reading the patterns to form corresponding read signal portions, and a third step of deriving a value of a read parameter from each read signal portion. The invention also relates to a method for setting an optimum value of write power level of the radiation beam.

The invention further relates to an optical recording apparatus for recording information on an optical recording medium, comprising a radiation source having a controllable value of a write power level for emitting a radiation beam for recording information on the recording medium, a control unit for recording a series of test patterns, each pattern with a different value of the write power level, a read unit for reading the patterns and forming corresponding read signal portions, and first means for deriving a value of a read parameter from each read signal portion.

The invention further relates to an optical recording medium for recording information by irradiating the recording medium by a radiation beam, the recording medium comprising an area containing control information indicative of a recording pocess by which information can be recorded on that recording medium, the control information comprising values of recording parameters for the recording process.

A method and apparatus according to the first paragraph are known from the European patent application no. EP 0 737 962. The apparatus uses a method for setting the optimum write power (P_{opt}) of the radiation beam having the following steps. First the apparatus records a series of test patterns on the recording medium, each pattern with increasing write power (P). Next, it derives the modulation (M) of each pattern from the read signal corresponding to the pattern. It calculates the derivative of the modulation (M) as a function of the write power (P) and normalizes the derivative by multiplying it by the write power (P) over the modulation (M). The intersection of the normalized derivative (γ) with a

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JC580 U.S. PTO
09/966792
10/16/01

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Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

00125983.7

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preset value (γ_{target}) determines a target write power level (P_{target}). Finally, the target write power (P_{target}) is multiplied by a parameter (ρ) to obtain a write power level (P_{opt}) suitable for recording on the recording medium. The value of the parameter (ρ) is read from the recording medium itself. The test patterns are recorded on the recording medium by applying write power (P) values in a range around a given value (P_{ind}) which is also read from the recording medium itself.

In an optical recording apparatus it is important to record information on optical recording media with the correct power of the laser beam. A media manufacturer can not give this correct power in an absolute way (e.g., pre-recorded on the disc) because of environment and apparatus -to- apparatus deviations for every recording medium and recording apparatus combination. The known method for setting the optimum write power (P_{opt}) takes the different characteristics of the recording media into account by measuring the modulation (M) of the test patterns written on the recording media. Furthermore, this method is independent of the specific recording apparatus. The method is designed for providing a proper setting of the write power for each combination of recording apparatus and recording medium.

However, it is a disadvantage of the known method that it is not always possible to determine an accurate and unambiguous value for the target write power level (P_{target}) and therefore for the optimal value (P_{opt}) of the write power level (P). This is because of the measurement noise introduced during the measurement of the values for the modulation (M) of each pattern. This measurement noise increases with decreasing write power (P) of the test patterns. It appears that even when the measured modulation values are averaged, so as to reduce the measurement noise, sometimes a sort of plateau in the γ-curve occurs preventing the determination of an unambiguous value for the target write power level (P_{target}).

It is an object of the present invention to provide a method according to the opening paragraph which determines an accurate and unambiguous optimum value for a write parameter, from which write parameter an optimal value (P_{opt}) of the write power level (P) can be derived.

This object is achieved when the method of the preamble is characterized in that the method further comprises a fourth step of curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter

and of the write power level (P), and a fifth step of setting an optimum value of the write parameter in dependence on a property of the curve-fitted function.

It is observed that in the known method the noise in the measurement of the read parameter is significantly attenuated by the differentiation step necessary to obtain the normalized derivative (γ). In the method according to the invention this differentiation step is omitted and a function is curve-fitted directly to the values of the read parameter versus the values of the write power level. This curve-fitting may be done by any fitting algorithm such as, for example, the well-known least-squares algorithm. From this curve-fitted function an optimum value of the write parameter is obtained.

In general, any function defining a relation between the read parameter and the write power level (P) having any shape can be used. However, it should be noted that a straight line can very easily and accurately be curve-fitted. Therefore, arranging the values of the read parameter and of the write power level (P) in such a way that a straight line could be curve-fitted is advantageous and should be preferred.

In a version of the method according to the invention the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium. This modulation (M) is computed from the following expression

$$M = ((I_H - I_L) / I_H) \cdot 100,$$

where I_H is the highest level of the amplitude and I_L is the lowest level of the amplitude in the read signal derived from reading information recorded on the information carrier comprising longer marks such as, for example, marks having a length of 14 times the channel bit length when Eight-to-Fourteen Modulation Plus (EFM+) coding is employed.

A preferred version of the method according to the invention is characterized in that the curve-fitted function is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

wherein α and β have values resulting from the curve-fitting, and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

When the values of the modulation (M) times the write power level (P) are plotted versus the write power level (P), a function represented by a substantially straight line can be curve-fitted. Physically this straight line is limited by the lowest write power and the highest write power used when writing the series of test patterns. It is an advantage of this version of the method according to the invention that a straight line can very easily and accurately be curve-fitted by known fitting algorithms.

The curve-fitted straight line is described by its properties α and β. The optimum value of the write parameter is set to be substantially equal to the value of β, i.e. the value for the power level (P) for which the extrapolated straight line crosses the P-axis. It is a further advantage of this version of the method according to the invention that each straight line has just a single crossing with each of the axes. Therefore, the optimum value of the write parameter can unambiguously be determined because there is only a single crossing of the curve-fitted straight line with the P-axis.

A version of the method according to invention is characterized in that the curve-fitting of the straight line in the fourth step is carried out in a predetermined fit range of write power levels. Because the curve fitted straight line is a first order approximation of the relation between the read parameter and the write power level, the curve-fit should be carried out in an appropriate fit range of write power levels.

Such an appropriate fit range is, for example, a range of write power levels around an indicative power level (P_{ind}) recorded on the recording medium as control information indicative of the recording process, e.g., a range in-between $\omega_1 \cdot P_{ind}$ and $\omega_2 \cdot P_{ind}$ where ω_1 and ω_2 are predetermined values. An especially advantageous fit range is found to be a range of write power levels in-between $0.85 \cdot P_{ind}$ and $1.15 \cdot P_{ind}$.

A preferred method according to the invention is characterized in that the method further comprises a step of curve-fitting a provisional straight line, and in that the predetermined fit range of write power levels is in-between $P_{fit} \cdot \omega_1$ and $P_{fit} \cdot \omega_2$, where P_{fit} is a value derived from the provisional curve-fitted straight line. ω_1 and ω_2 may have any value. However, an especially advantageous fit range is found to be a range of write power levels in-between $0.85 \cdot P_{fit}$ and $1.15 \cdot P_{fit}$.

It is noted that the provisional curve-fitted straight line itself can be obtained from curve-fitting it in a fit-range of power levels around a second value of P_{fit} derived from a second provisional curve-fitted straight line. In this way an iteration procedure can be created which results in an optimum fit range of power levels. Such an iteration procedure can start, for example, with a value of P_{fit} equal to the indicative power level (P_{ind}) recorded on the recording medium as control information indicative of the recording process. The iteration procedure can stop, for example, after a predetermined number of iteration steps or, alternatively, when P_{fit} changes less then a predetermined value between two consecutive iteration steps. It is further noted that when an iteration procedure is used, P_{fit} can be derived from the provisional straight line curve-fitted in the previous iteration step only.

Alternatively, P_{fit} can be derived from the provisional straight line curve-fitted in the previous iteration step combined with at least one provisional straight lines curve-fitted in earlier iteration steps.

A further method according to the invention is characterized in that the method further comprises a step of curve-fitting at least a second straight line in at least a second predetermined fit range of write power levels, and in that in the fifth step the optimum value of the write parameter is set in dependence on a property of each of the curve-fitted straight lines. The optimum value of the write parameter may, for example, be set to the mean value of the optimum values resulting from each individual curve-fitted straight line. Alternatively, a weighted mean value can be used or a value resulting from an interpolation procedure between the optimum values resulting from each individual curve-fitted straight line. Such an interpolation procedure may be either linear or non-linear. When two straight lines are use, the first fit range of write power levels can, for example, be set to a range around the indicative power level (P_{ind}) minus a fixed value while the second fit range is set to a range around the indicative power level (P_{ind}) plus the fixed value. The fixed value may be selected, for example, from a range between 0.25 mW and 1.0 mW.

It is also an object of the present invention to provide a method according to the opening paragraph which determines an accurate and unambiguous optimum value (P_{opt}) of the write power level (P) of the radiation beam. The optimum value (P_{opt}) of the write power level (P) is defined as the write power (P) for which the lowest jitter of the read signal from information recorded on the recording medium is obtained.

This object is achieved when the method of the preamble, the radiation beam having a write power level, is characterized in that the curve-fitted function is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

wherein α and β have values resulting from the curve-fitting, the optimum value of the write parameter is set to be substantially equal to the value of β, and the optimal value (P_{opt}) of the write power level (P) of the radiation beam is set to be equal to the optimum value of the write parameter times a multiplication constant (κ).

After the optimum value of the write parameter has been determined, i.e. is set to be substantially equal to the value of β, an optimal value (P_{opt}) of the write power level (P) of the radiation beam is obtained by multiplying the optimum value of the write parameter by

a multiplication constant (κ). Thus an optimal value (P_{opt}) of the write power level (P) is found from

$$P_{opt} = \kappa \cdot \beta$$

The value of the multiplication constant (κ) depends on properties of the recording medium on which information is to be recorded. It should be noted that the value for the multiplication constant (κ) can be derived from the values for the parameter (ρ) and for the preset value (γ_{target}) of the known method by the formula

$$\kappa = \rho \cdot (1 + 1/\gamma_{target}).$$

A version of the method according to the invention is characterized in that the multiplication constant (κ) is read from an area on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium.

Because the value of the multiplication constant (κ) depends solely on properties of the recording medium, it can be determined by the manufacturer and pre-recorded on the recording medium during manufacture. Alternatively, the value of the multiplication constant (κ) can be determined by the user and recorded on the recording medium for later use. The method now reads the value of the multiplication constant (κ) from the recording medium when an optimum value (P_{opt}) of the write power level (P) has to be set for recording information on that recording medium.

It is a further object of the present invention to provide a apparatus according to the opening paragraph which determines an accurate and unambiguous optimum value for a write parameter, from which write parameter an optimal value (P_{opt}) of the write power level (P) can be derived.

This object is achieved when the apparatus of the preamble is characterized in that the apparatus further comprises second means for curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P), and third means for setting an optimum value of a write parameter in dependence on a property of the curve-fitted function.

An embodiment of the apparatus according to the invention is characterized in that the second means are arranged for curve-fitting a function represented by a substantially straight line to the values of the read parameter and of the write power level (P).

An embodiment of the apparatus according to the invention is characterized in that the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium, in that the curve-fitted function is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

wherein α and β have values resulting from the curve-fitting. In a preferred embodiment of the apparatus according to the invention, the optimum value of the write parameter is subsequently set to be substantially equal to the value of β.

An embodiment of the apparatus according to the invention is characterized in that the second means (101) for curve-fitting a function are arranged for setting a predetermined fit range of power levels. The predetermined fit range may be set in dependence on a value (P_{ind}) indicative of the fit range read from an area on the recording medium comprising control information indicative of the recording process e.g., a range in-between $\omega_1 \cdot P_{ind}$ and $\omega_2 \cdot P_{ind}$ where ω_1 and ω_2 are predetermined values. An especially advantageous fit range is found to be a range of write power levels in-between $0.85 \cdot P_{ind}$ and $1.15 \cdot P_{ind}$.

An embodiment of the apparatus according to the invention is characterized in that the apparatus comprises fourth means for curve-fitting a provisional straight line to the values of the read parameter and of the write power level (P) and fifth means for setting a value P_{fit} in dependence on a property of the curve-fitted provisional straight line, and in that the second means (101) are arranged for setting the predetermined fit range of power levels in-between P_{fit} times ω_1 and P_{fit} times ω_2 where ω_1 and ω_2 are predetermined values. It is noted that the provisional curve-fitted straight line itself can be obtained from curve-fitting it in a fit-range of power levels around a second value of P_{fit} derived from a second provisional curve-fitted straight line. In this way an iteration procedure can be created which results in an optimum fit range of power levels. It is further noted that the second means for curve-fitting the straight line and the fourth means for curve-fitting the provisional straight line may be separate devices or, alternatively, may be combined into a single device.

An embodiment of the apparatus according to the invention is characterized in that the apparatus comprises fourth means for curve-fitting a second straight line in a second predetermined fit range of power levels, and in that the third means (102) are arranged for setting an optimum value of the write parameter in dependence on a property of each of the curve-fitted straight lines. Again, the second means for curve-fitting the straight line and the

fourth means for curve-fitting the second straight line may be separate devices or, alternatively, may be combined into a single device.

An embodiment of the apparatus according to the invention is characterized in that the apparatus comprises setting means for setting an optimum value (P_{opt}) of the write power level (P) in dependence on the optimum value of the write parameter.

An embodiment of the apparatus according to the invention, the read unit operative for reading a value of a multiplication constant (κ) from an area on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium, is characterized in that the setting means are arranged for setting an optimum value (P_{opt}) of the write power level (P) by multiplying the optimum value of a write parameter by the multiplication constant (κ).

It is a further object of the present invention to provide an optical recording medium for use by the method and the optical recording apparatus of the present invention.

This object is achieved when the optical recording medium of the preamble is characterized in that the control information comprises a value of a multiplication constant (κ).

Because the value of the multiplication constant (κ), used by the method and the apparatus for setting the optimal value (P_{opt}) of the write power level (P), depends solely on properties of the recording medium, it can be determined by the manufacturer and pre-recorded on the recording medium during manufacture.

It should be noted that an optical recording medium is known from the International patent application no. WO 98/25266. However, the control information contained on this known recording medium comprises a preset value (γ_{target}) which, in the known method and apparatus for setting an optimum value for a write parameter, is compared to the values of the normalized derivative (γ) of the modulation (M) versus the write power (P). The optical recording medium according to the present invention comprises a multiplication constant (κ) which is used to obtain an optimum value (P_{opt}) of the write power level (P) by multiplying this multiplication constant (κ) with the optimum value of a write parameter. Furthermore, this optimum value of a write parameter is derived without using a derivative of the modulation (M) versus the write power (P).

This object is also achieved when the optical recording medium of the preamble is characterized in that the control information comprises a value indicative of the

fit range (P_{ind}). P_{ind} can be determined by the manufacturer and pre-recorded on the recording medium during manufacture. For determining P_{ind}, media manufacturers have to find the optimum value (P_{REF}) of the write power level (P) for their recording medium in a reference recording apparatus and under standardized conditions. Now P_{ind} can be derived, for example, from P_{REF} from either of the formulas

$$P_{ind} = P_{REF} / \rho, \text{ or}$$

$$P_{ind} = (P_{REF} / \kappa) \cdot (1 + 1/\gamma_{target}).$$

The objects, features and advantages of the invention will be apparent from the following more particular descriptions of examples of embodiments of the invention, as illustrated in the accompanying drawings where,

Figure 1 is a diagram of an embodiment of an optical recording apparatus according to the invention,

Figure 2 illustrates two read signal portions from two test patterns,

Figure 3 is a graph showing the measured modulation time the write power as a function of the write power and the curve-fitted function,

Figure 4 is a flow-chart of a first version of the method according to the invention,

Figure 5 shows an embodiment of a recording medium according to the invention,

Figure 6 is a flow chart of a procedure for setting the predetermined fit range, and

Figure 7 is a flow chart of a second version of the method according to the invention.

Figure 1 shows an optical recording apparatus and an optical recording medium 1 according to the invention. Recording medium 1 has a transparent substrate 2 and a recording layer 3 arranged on it. The recording layer 3 comprises a material suitable for recording information by means of a radiation beam 5. The recording material may be of for example the magneto-optical type, the phase-change type, the dye type or any other suitable material. Information may be recorded in the form of optically detectable regions, also called marks, on recording layer 3. The apparatus comprises a radiation source 4, for example a semiconductor laser, for emitting a radiation beam 5. The radiation beam is converged on recording layer 3 via a beam splitter 6, an objective lens 7 and substrate 2. The recording

medium may alternatively be air-incident, where the radiation beam is directly incident on recording layer 3 without passing through a substrate. Radiation reflected from medium 1 is converged by objective lens 7 and, after passing through beam splitter 6, falls on a detection system 8, which converts the incident radiation in electric detector signals. The detector signals are input to a circuit 9. This circuit 9 derives several signals from the detector signals, such as a read signal S_R representing the information being read from recording medium 1. Radiation source 4, beam splitter 6, objective lens 7, detection system 8 and circuit 9 form together a read unit 90.

The read signal from circuit 9 is processed in a first processor 10 in order to derive signals representing a read parameter from the read signal. The derived signals are fed in a second processor 101 and subsequently into a third processor 102 which processors process a series of values of the read parameter and based thereon derive a value for a write power control signal necessary for controlling the laser power level.

The write power control signal is connected to a control unit 12. An information signal 13, representing the information to be recorded on the recording medium 1, is also fed into control unit 12. The output of control unit 12 is connected to radiation source 4. A mark on recording layer 3 can be recorded by a single radiation pulse, the power of which is determined by the optimum write power level (P_{opt}) as determined by processor 102. Alternatively, a mark can also be recorded by a series of radiation pulses of equal or different lengths and one or more power levels determined by the write power signal.

A processor is understood to mean any means suitable for performing calculations, e.g. a microprocessor, a digital signal processor, a hard-wired analog circuit or a field programmable circuit. Moreover, first processor 10, second processor 101 and third processor 102 may be separate devices or, alternatively, may be combined into a single device executing all three processes.

Before recording information on medium 1 the apparatus sets its write power (P) to the optimum value (P_{opt}) by performing a method according to the invention. This method is schematically depicted in the flow-chart shown in figure 4.

In a first step 41 the apparatus writes a series of test patterns on medium 1. The test patterns should be selected so as to give a desired read signal. If the read parameter to be derived from the read signal is the modulation (M) of a read signal portion pertaining to a test pattern, the test pattern should comprise marks sufficiently long to achieve a maximum modulation of the read signal portion. When the information is coded according to the so-called Eight-to-Fourteen modulation (EFM), the test patterns preferably comprise the long

I11 marks of the modulation scheme. When the information is coded according to the Eight-to-Fourteen Plus modulation (EFM+), the test patterns should comprise the long I14 marks of this modulation scheme. The test patterns are recorded each with a different write power level (P). The range of the powers can be selected on the basis of an indicative power level (P_{ind}) recorded as control information on the recording medium. Subsequent test patterns may be recorded with a step-wise increased write power level (P) under the control of control unit 12. The test patterns may be written anywhere on the recording medium. They can alternatively be written in specially provided test areas on the recording medium.

In a second step 42 the recorded test patterns are read by read unit 90 to form a read signal S_R. Figure 2 shows the read signal portions 18 and 19 obtained from two test patterns written at two different write power levels. The drawn patterns comprise a short mark, a long mark and a short mark, as shown by the signal parts 15, 16 and 17, respectively in both read signal portion 18 and read signal portion 19. An actual pattern may comprise a few hundred marks of different or equal lengths.

In a third step 43 processor 10 derives from the read signal S_R a read parameter for each read signal portion. A possible read parameter is the ratio of the lowest level of the amplitude of a read signal portion, for read signal portion 18 indicated by 'a' in Figure 2, and the maximum level of the amplitude of the same read signal portion, indicated by 'b'. A preferred read parameter is the modulation (M), being the ratio of the maximum peak-to-peak value of a read signal, indicated by 'c', and the maximum amplitude 'b' of the read signal portion.

In a fourth step 44 processor 101 forms a series of value pairs for the modulation (M) of a pattern times the write power (P) and the write power (P) with which that pattern has been written. The write powers can be taken from the value of the write power control signal during recording the test patterns or, alternatively, from a measurement of the radiation power.

Figure 3 shows schematically the result of the processed read signal obtained from the test patterns; each dot 21 represents a pair of values for the modulation (M) times the write power (P) and the write power (P) of a test pattern. Processor 101 fits a straight line 22 through the measured modulation values (M) times the write power (P), i.e. M·P. The fitted straight line is indicated in Figure 3 by a solid line 22. The fitting may be done by the well known least-squares fitting algorithm. The straight line 22 is curve-fitted to the dots 21 in a predetermined fit range 28 of write power levels. In this example the fit range is centered around a value P_{ind} indicative of the fit range read from an area on the recording medium. The

fitted straight line 22 may be extrapolated. The extrapolated straight line is indicated in Figure 3 by a dashed line 24.

In a fifth step 45 processor 102 determines an analytic expression describing the fitted straight line. This expression is of the form

$$P \cdot M = \alpha \cdot (P - \beta),$$

where parameters α and β have values resulting from the curve-fitting. The value for the write parameter β determined by the curve fitting is now used by processor 102 to set the optimal value (P_{opt}) for the write power (P). This is done by multiplying this value for the write parameter β with a value of a multiplication constant (κ). So, the optimal value (P_{opt}) for the write power (P) is found from

$$P_{opt} = \kappa \cdot \beta.$$

The multiplication constant (κ) depends on properties of the recording medium 1 and may be pre-recorded in an control area 32 of the recording medium 1. If so, the multiplication constant (κ) is read from the recording medium 1 by the read unit 90.

It should be mentioned that the value for the write parameter β determined by the curve fitting corresponds to the value of the write power (P) for which the extrapolated straight line 24 crosses the P-axis 26. This value of the write power (P), and therefore of the write parameter β, is indicated by reference number 25 in Figure 3.

An example of a procedure for setting the predetermined fit range 28 of write power levels in an iterative manner is schematically depicted in the flow-chart shown in figure 6. In a step 60, a value P_{ind} indicative of the fit range is read from an area on the recording medium 1. In step 611 an initial fit range is set from $0.85 \cdot P_{ind}$ to $1.15 \cdot P_{ind}$. In a next step 621, a first provisional straight line is curve-fitted to the dots 21 in the initial fit range. From this first provisional straight line a first fit value $P_{fit,1}$ is derived in step 631. In a next sequence of the iteration procedure the fit range is set in step 612 from $0.85 \cdot P_{fit,1}$ to $1.15 \cdot P_{fit,1}$. In step 622 again a provisional straight line is curve-fitted to the dots 21 and from this second provisional straight line a second fit value $P_{fit,2}$ is derived in step 632. Now, in step 44, a straight line 22 is curve fitted to the dots 21 in a predetermined fit range 28 set from $0.85 \cdot P_{fit,2}$ to $1.15 \cdot P_{fit,2}$.

Each fit value $P_{fit,N}$ is derived from the N-th provisional curve-fitted straight line. A good value $P_{fit,N}$ is found from

$$P_{fit,N} = (\kappa \cdot \beta_N) / \rho,$$

where β_N corresponds to the value of the write power (P) for which the extrapolated N-th provisional straight line crosses the P-axis 26. Moreover, the fit value $P_{fit,N}$ may be derived not only from the N-th provisional straight line, but also from fit values in earlier step of the iteration procedure, i.e.,

$$P_{fit,N} = f(\ (\kappa \cdot \beta_N / \rho), P_{ind}, P_{fit,N-1}, P_{fit,N-2}, \ldots).$$

Particularly good values for values for $P_{fit,1}$ and $P_{fit,2}$ are found to be

$$P_{fit,1} = (P_{ind} + (\kappa \cdot \beta_1) / \rho) / 2, \text{ and}$$

$$P_{fit,2} = (P_{fit,1} + (\kappa \cdot \beta_2) / \rho) / 2.$$

In the above example the iteration procedure consists of three iteration steps. It is noted however that any other number of iteration steps may be used. Moreover, besides using a fixed number of iteration steps, the iteration procedure may, alternatively, continue until a stop criterion is reached. Such a stop criterion is for example that P_{fit} changes less then a predetermined value between two consecutive iteration steps.

Figure 7 shows schematically a flow-chart of a second version of the method according to the invention. Instead of curve fitting a single straight line in the fourth step 44 of the method, two straight lines are curve-fitted. In step 441 a first straight line is curve fitted in a first predetermined fit range and in step 442 a second straight line is curve fitted in a second predetermined fit range. The first fit range is centered around P_{ind}-0.5mW while the second fit range is centered around P_{ind}+0.5mW. Other ranges may, alternatively, be used. The first curve-fitted straight line is described by the expression $P \cdot M = \alpha_1 \cdot (P-\beta_1)$, while the second curve-fitted straight line is described by the expression $P \cdot M = \alpha_2 \cdot (P-\beta_2)$.

In the fifth step 45 of the method, the optimum value (P_{opt}) for the write power is dependent on both β_1 and β_2. For example, P_{opt} may be derived from the mean value of β_1 and β_2, i.e.,

$$P_{opt} = \kappa \cdot (\beta_1 + \beta_2)/2.$$

Alternatively, P_{opt} may be derived from a linear interpolation between β_1 and β_2 where the respective fit ranges are taking into account

Figure 5a shows an embodiment of recording medium 1 provided with a track 30. The track may be circular or spiral and in the form of, for example, an embossed groove or ridge. The area of the recording medium is divided in an information recording area 31 for recording user information and a control area 32 for storing information relevant for writing, reading and erasing information on the recording medium and in general not intended for recording user information. Control area 32 is marked by a dashed track in figure 5. Information recording area 31 is of a type which is subject to change in an optically

detectable property when exposed to radiation above a specific write power level. Information on the recording medium is represented by patterns of marks.

Information is recorded in a track 30 in the information recording area 31 by a recording process in which each mark is formed by one ore more recording pulses of constant or varying write power depending on, for example, the length of the marks to be recorded. The recording parameters for this recording process are stored in the control area 32 in the form of patterns of marks 34 representing the control information indicative of the recording process. Figure 5b shows a strongly enlarged portion 33 of track 30 comprising an example of a pattern of marks 34 in which the control information is encoded.

The value of the multiplication constant κ and of the value indicative of the fit range P_{ind} are stored as patterns of marks representing control information in control area 32 of the recording medium 1. When the control area 32 is embossed, the manufacturer of the medium must pre-record the values for κ and P_{ind} during manufacture. Alternatively, the user can record the value for κ on the recording medium during, for example, initialization of the recording medium.

Alternatively, a recording medium provided with control information in a different manner may be used. Such an alternative recording medium is, for example a recording medium having the control information indicative of the recording process encoded in a periodic modulation of an embossed groove (known as a wobble). Now the values for the multiplication constant κ and for the value indicative of the fit range P_{ind} are coded in an auxiliary signal which auxiliary signal is used to, for example, frequency-modulate the wobble. A description of such a recording medium may be found in EP 0 397 238.

It should be noted that the above mentioned versions and embodiments illustrate rather than limit de invention, and that those skilled in the art will be able to design alternatives without departing from the scope of the appended claims. For example, the invention has been explained by an embodiment using the read signal modulation (M) as read parameter and a disc shaped recording medium. However, it will be clear to a skilled man that other read parameters and other shapes of the recording medium can be employed alternatively. The jitter of the read signal can, for example, alternatively be used as a read parameter. Moreover, in the claims, any reference sign placed between parentheses shall not be construed as limiting the claim. The word "comprise" and its conjugations do not exclude the presence of steps or elements other than those listed in the claims.

CLAIMS:

1. A method for setting an optimum value of a write parameter for use in an optical recording apparatus for writing information on an optical recording medium (1) by a radiation beam (5),
the method comprising a first step (41) of writing a series of test patterns on the recording medium, each pattern with a different value of a write power level (P) of the radiation beam,
a second step (42) of reading the patterns to form corresponding read signal portions (18, 19), and
a third step (43) of deriving a value of a read parameter from each read signal portion,
characterized in that the method further comprises a fourth step (44) of curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P),
and a fifth step (45) of setting an optimum value of the write parameter in dependence on a property of the curve-fitted function.

2. A method according to claim 1, characterized in that in the fourth step (44) a function represented by a substantially straight line (22) is curve-fitted to the values of the read parameter and of the write power level (P).

3. A method according to claim 1 or 2, wherein the read parameter is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium.

4. A method according to claim 3, characterized in that the curve-fitted function (22) is of the form $P{\cdot}M = \alpha{\cdot}(P-\beta)$,
wherein α and β have values resulting from the curve-fitting,
and in that the optimum value of the write parameter is set to be substantially equal to the value of β.

5. A method according to claim 2 or 4, characterized in that the curve-fitting of the straight line in the fourth step is carried out in a predetermined fit range (28) of write power levels.

6. A method according to claim 5, characterized in that the predetermined fit range of write power levels is in-between P_{ind} times ω_1 and P_{ind} times ω_2, where P_{ind} is a value read from an area on the recording medium comprising control information indicative of the recording process and where ω_1 and ω_2 are predetermined values.

7. A method according to claim 5, characterized in that the method further comprises a step of curve-fitting a provisional straight line, and in that the predetermined fit range of write power levels is in-between P_{fit} times ω_1 and P_{fit} times ω_2, where P_{fit} is a value derived from the provisional curve-fitted straight line and where ω_1 and ω_2 are predetermined values.

8. A method according to claim 6 or 7, characterized in that ω_1 has a value substantially equal to 0.85 and ω_2 has a value substantially equal to 1.15.

9. A method according to claim 5, characterized in that the method further comprises a step of curve-fitting at least a second straight line in at least a second predetermined fit range of write power levels, and in that in the fifth step the optimum value of the write parameter is set in dependence on a property of each of the curve-fitted straight lines.

10. A method for setting an optimum value (P_{opt}) of a write power level (P) of a radiation beam, for use in an optical recording apparatus for writing information on an optical recording medium (1) by the radiation beam (5) having the write power level (P), using a method according to any of the claims 4 to 9 for setting an optimum value of a write parameter, characterized in that the optimal value (P_{opt}) of the write power level (P) is set to be equal to the optimum value of the write parameter times a multiplication constant (κ).

11. A method according to claim 10, characterized in that the multiplication constant (κ) is read from an area (32) on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium.

12. An optical recording apparatus for recording information on an optical recording medium (1), comprising a radiation source (4) for emitting a radiation beam (5) having a controllable value of a write power level (P) for recording information on the recording medium,
a control unit (12) for recording a series of test patterns, each pattern with a different value of the write power level,
a read unit (90) for reading the patterns and forming corresponding read signal portions (18, 19), and
first means (10) for deriving a value of a read parameter from each read signal portion,
characterized in that the apparatus further comprises second means (101) for curve-fitting a function defining a relation between the read parameter and the write power level (P) to the values of the read parameter and of the write power level (P), and
third means (102) for setting an optimum value of a write parameter in dependence on a property of the curve-fitted function.

13. An apparatus according to claim 12, characterized in that the second means (101) are arranged for curve-fitting a function represented by a substantially straight line (22) to the values of the read parameter and of the write power level (P).

14. An apparatus according to claim 13, characterized in that the read parameter derived by the first means (10) is a modulation (M) of the amplitude of a read signal derived from information recorded on the recording medium, and in that the curve-fitted function (22) represented by a substantially straight line is of the form $P\cdot M = \alpha\cdot(P-\beta)$, wherein α and β have values resulting from the curve-fitting.

15. An apparatus according to claim 14, characterized in that the third means (102) are arranged for setting the optimum value of the write parameter substantially equal to the value of β.

16. An apparatus according to claim 13 or 14, characterized in that the second means (101) for curve-fitting a function are arranged for setting a predetermined fit range (28) of power levels.

17. An apparatus according to claim 16, the read unit (90) operative for reading a value (P_{ind}) indicative of the fit range from an area on the recording medium comprising control information indicative of the recording process, characterized in that the second means (101) are arranged for setting the predetermined fit range of power levels in-between P_{ind} times ω_1 and P_{ind} times ω_2,
where ω_1 and ω_2 are predetermined values.

18. An apparatus according to claim 16, characterized in that the apparatus comprises fourth means for curve-fitting a provisional straight line to the values of the read parameter and of the write power level (P) and fifth means for setting a value P_{fit} in dependence on a property of the curve-fitted provisional straight line, and in that the second means (101) are arranged for setting the predetermined fit range of power levels in-between P_{fit} times ω_1 and P_{fit} times ω_2,
where ω_1 and ω_2 are predetermined values.

19. An apparatus according to claim 16, characterized in that the apparatus comprises fourth means for curve-fitting a second straight line in a second predetermined fit range of power levels, and in that the third means (102) are arranged for setting an optimum value of the write parameter in dependence on a property of each of the curve-fitted straight lines.

20. An apparatus according to any of the claims 14 to19, characterized in that the apparatus comprises setting means for setting an optimum value (P_{opt}) of the write power level (P) in dependence on the optimum value of the write parameter.

21. An apparatus according to claim 20, the read unit (90) operative for reading a value of a multiplication constant (κ) from an area (32) on the recording medium containing control information indicative of a recording process by which information can be recorded on that recording medium, characterized in that the setting means are arranged for setting an

optimum value (P_{opt}) of the write power level (P) by multiplying the optimum value of a write parameter by the multiplication constant (κ).

22. An optical recording medium (1) for recording information by irradiating the recording medium by a radiation beam (5), the recording medium comprising an area (32) containing control information indicative of a recording process by which information can be recorded on that recording medium, the control information comprising values of recording parameters for the recording process,
characterized in that the control information comprises a value of a multiplication constant (κ) for use in the method according to claim 5 or the apparatus according to claim 9.

23. An optical recording medium (1) for recording information by irradiating the recording medium by a radiation beam (5), the recording medium comprising an area (32) containing control information indicative of a recording process by which information can be recorded on that recording medium, the control information comprising values of recording parameters for the recording process,
characterized in that the control information comprises a value indicative of the fit range (P_{ind}) for use in the method according to claim 6 or the apparatus according to claim 17.

ABSTRACT:

Methods and an optical recording apparatus using these methods are described in which an optimum write power of a radiation beam in the apparatus is set by writing a series of test patterns on the optical recording medium, forming a read signal from the patterns and processing the read signal. This processing involves fitting a function, preferably a straight line, to parameters obtained from the read signal without having to perform a differentiation step. Also an optical recording medium for use by the methods and the apparatus is described.

Add Figure 1

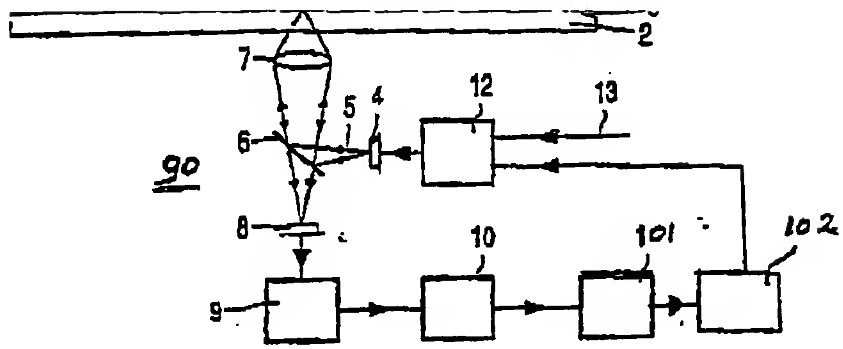

FIG. 1

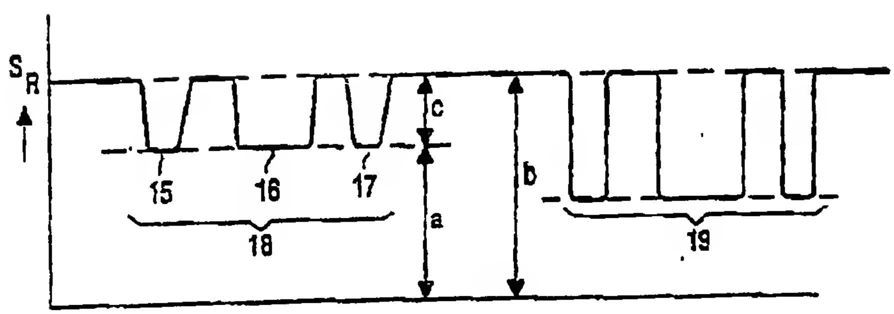

FIG. 2

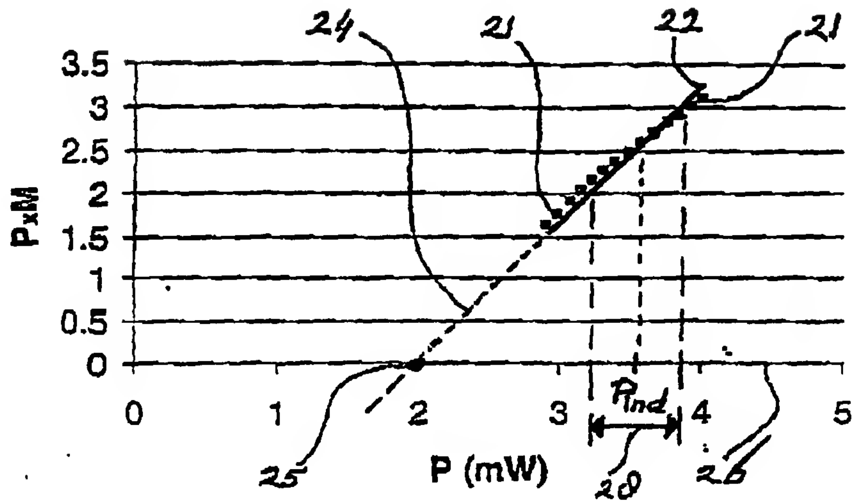
24
21
22
21
3.5
3
2.5
2
1.5
1
0.5
0
PxM
0
1
2
3
4
5
P (mW)
Pind
25
20
26

FIG. 3

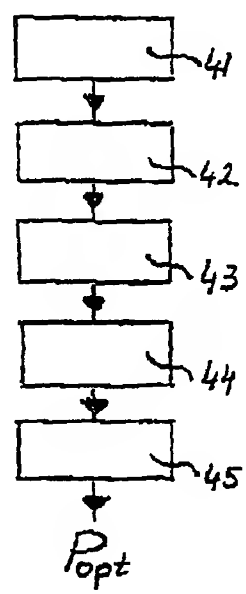
41
42
43
44
45
Popt

FIG. 4

PHNL000685

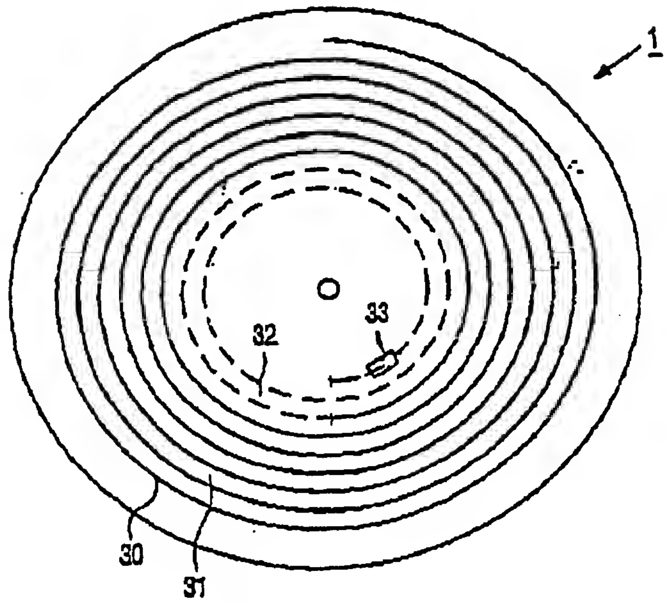

FIG. 5A

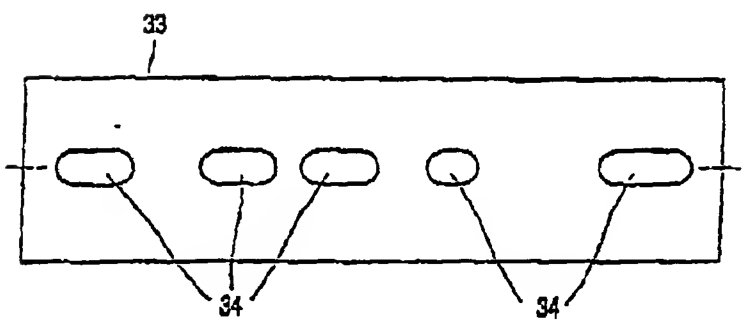

FIG. 5B

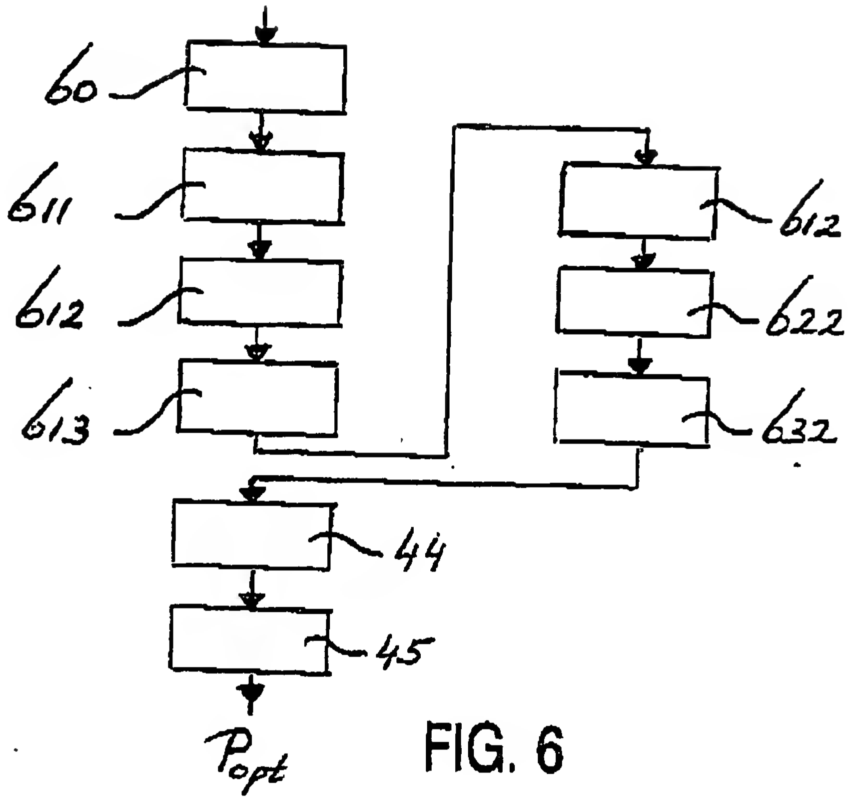

FIG. 6

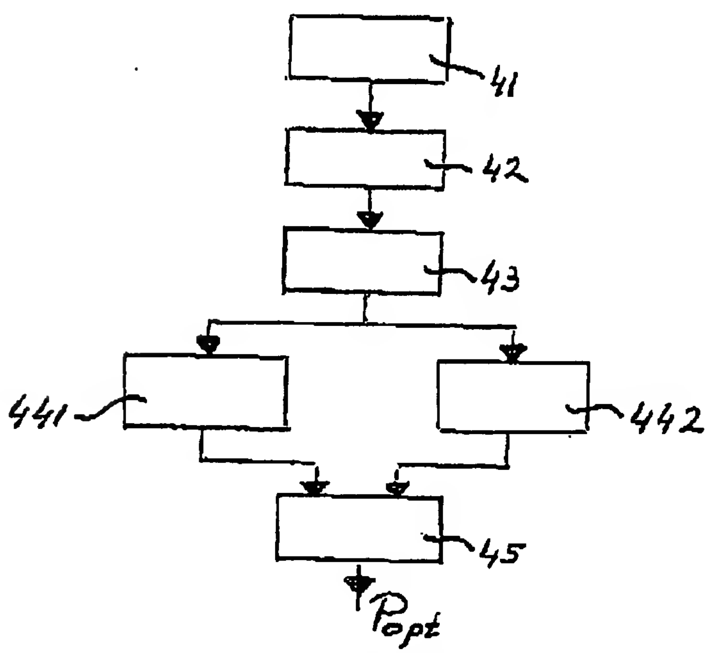

FIG. 7